MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(All sections/Groups)

1 JUNE 2016
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Answer **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (25 marks)

(a) According to ray theory, light propagates in an optical fiber through total internal reflection.

(i) Briefly describe how total internal reflection occurs. [3 marks]

(ii) Describe TWO (2) conditions that must be fulfilled in order for total internal reflection to occur in an optical fiber. [2 marks]

(b) The cladding of an optical fiber sample has been removed and the fiber sample is exposed to water. The refractive index of the core is 1.467. Assume the refractive index of the water is 1.333.

(i) Can light propagate in the core of the fiber without the cladding? Justify your answer. [3 marks]

(ii) Calculate the numerical aperture of the fiber sample. [2 marks]

(iii) Calculate the acceptance angle of the fiber sample. [2 marks]

(iv) At a wavelength of 1550 nm, what is the maximum core diameter for the optical fiber in order for it to be a single mode fiber? [3 marks]

(c) An optical fiber has a loss of 0.25 dB/km at a wavelength of 1550 nm. A communication link with a length of 100 km was launched with a power of 0.5 dBm at the wavelength 1550 nm.

(i) Determine the total loss in the communication link due to the optical fiber only. [1 mark]

(ii) Calculate the received power (in Watts) at the end of the 100 km of fiber. [3 marks]

(d) Attenuation in optical fibers can be caused by scattering, absorption and bending.

(i) Compare TWO (2) differences between Rayleigh scattering and Mie scattering, which are both linear scattering that can cause attenuation in optical fibers. [4 marks]

(ii) How can we reduce the effects of intrinsic absorption in an optical fiber? [2 marks]

Continued .....

Question 2 (25 marks)

(a) Laser diode is a coherent source and have a spectral bandwidth of less than 1 nm.

(i) Describe how coherency is achieved in a laser diode. Your answer must include the process of how light is emitted in a laser diode. [5 marks]

(ii) What is the advantage of having a spectral bandwidth of less than 1 nm? [1 marks]

(b) Describe how an avalanche photodetector works. [5 marks]

(c) With the help of suitable energy state diagrams (initial and final state), describe how light is transmitted in a light emitting diode (LED). [3 marks]

(d) A photodiode with a quantum efficiency of 0.5 is detecting 10^{11} photons per second at the wavelength of 1550 nm. Calculate:

(i) The energy of the incident radiation (in eV, electron volt). [3 marks]

(ii) The responsivity of the photodiode. [2 marks]

(iii) The received optical power of the photodiode. [2 marks]

(iv) The output photocurrent. [2 marks]

(v) The output photocurrent if the photodiode is an avalanche photodiode with a multiplication factor of 15. [2 marks]

Continued .....

Question 3 (25 marks)

(a) Two categories of optical amplifiers are semiconductor laser amplifiers and doped fiber amplifiers.

(i) Describe TWO (2) characteristics of semiconductor laser amplifiers. [4 marks]

(ii) Briefly describe TWO (2) types of semiconductor laser amplifiers. [4 marks]

(iii) In an optical communication network, illustrate THREE (3) applications of optical amplifiers. [6 marks]

(b) An Erbium doped amplifier with a gain of 22 dB produces an output power of 25 dBm at 1550 nm. Calculate:

(i) The input power in dBm. [2 marks]

(ii) The minimum pump power required when it is pumped at 980 nm. [2 marks]

(c) Two types of digital modulation scheme are non-return-to-zero (NRZ) and return-to-zero (RZ).

(i) Propose TWO (2) types of systems where RZ modulation scheme is more commonly used and justify your answer. [4 marks]

(ii) NRZ and RZ system are called linear optical systems because they use low intensity pulses. Describe ONE (1) advantage of linear optical system. [2 marks]

(iii) Briefly describe how intensity modulation modulates an optical signal. [1 mark]

Continued .....

Question 4 (25 marks)

As an optical communications engineer, you have been assigned to design an optical link between two cities 100 km apart. The requirements are summarized as follows:

Table Q4.1 Requirements

Bit-rate	2.5 Gb/s
Length	100 km
Minimum receiver power	-26 dBm
Modulation format	RZ
Power margin level	3 dB

You may consider the following optical sources and fiber choices (Table Q4.2 and Q4.3) in your design.

Table Q4.2 Optical Source

	DFB Laser 1	**DFB Laser 2**
Wavelength (nm)	1300	1550
Maximum Power (dBm)	-3	0
Spectral width (nm)	0.1	0.1
Transmitter rise-time (ns)	0.05	0.05

Table Q4.3 Optical Fiber

	Single Mode Fiber	**Multimode Fiber**
Attenuation at 1300 nm (dB/ km)	0.8	0.9
Attenuation at 1550 nm (dB/km)	0.25	0.25
Intermodal Dispersion Coefficient (ps/m)	0	10

Continued .....

(a) Propose a suitable optical source for your design. Justify your answer. [3 marks]

(b) Propose a suitable fiber type for your design. Justify your answer. [3 marks]

(c) Based on your answer in Q4 (b), calculate the total attenuation in your link due to the optical fiber only. [2 marks]

(d) Propose the amplifier type to be used in your design. Your answer should include the type of amplifier, gain of the amplifier and the number of amplifiers in your design. [3 marks]

(e) Calculate the output power at the end of the last amplifier as per your answer in Q4 (d). [4 marks]

(f) Propose the number of connectors to be used in your link and the loss induced by each connector after taking into account your answer in Q4 (a) – (d). [2 marks]

(g) Calculate the total loss in the system after taking into account your answer in Q4 (a) - (f). Your answer should include the power margin level shown in Table Q4.1. [2 marks]

(h) Taking into account the total losses in the network link as per your answer in Q4 (g), calculate the optical power budget for the transmission from optical source to receiver. Will your design work? Justify your answer. [6 marks]

Continued .....

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of Paper